International Journal of Agricultural Science and Research (IJASR)
ISSN(P): 2250-0057; ISSN(E): 2321-0087
Vol. 7, Issue 1, Feb 2017, 439-450

ADAPTATION AND MITIGATION STRATEGIES TO PROGRESS TOWARDS A CLIMATE-SMART AGRICULTURAL ECONOMY IN INDIA: A MACRO PERSPECTIVE

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ABSTRACT

Climate risk is an increasing concern in Indian agriculture dominated by small and marginal farms that have poor resource base making them more vulnerable. One of the key characteristics of climate change being increasing frequency of extreme weather events which are found to decrease crop yields. This paper provides an outline of the agriculture development programmes related to adaptation and mitigation within the agricultural production system in India, as they play a pivotal role via their convergence with broad climate related adaptation and mitigation strategies to progress towards a climate-smart agricultural economy. However, climate change mitigation has not been given equal priority as much as adaptation interventions. It is necessary to incorporate weather related early warning systems, pest and disease outbreak alerts, indigenous techniques to address climate change and protection of common property resources as mitigation strategies. Taking a leaf from the climate-smart agriculture advocated by the FAO, case studies from the Indian context were reviewed relating to the components on technology and computer based tools, capacity building of the farmers and service providers (agencies) and evolving policies promoting relevant institutions that are able to respond effectively to long-term risks associated with climate variability and climate change

KEYWORDS: Agriculture, Climate change, Adaptation, Mitigation, India & CSA

Received: Jan 03, 2017; **Accepted:** Jan 31, 2017; **Published:** Feb 04, 2017; **Paper Id.:** IJASRFEB201756

Original Article

INTRODUCTION

Climate risk is an increasing concern that has been exacerbated by high growth pressure accompanied by a surge in energy consumption and green house gas emissions. Globally, natural ecosystems are expected to change significantly in response to past as well as future climate change that can manifest through major transitions in landscapes and livelihoods. Agriculture in India, spread across 15 diverse agro-climatic zones and dominated by small and marginal farmers is a key economic and employment source that both contributes to and is threatened by climate change.

The tenth edition of the *Germanwatch* Global Climate Risk Index 2015 that indicates the level of exposure and vulnerability to extreme climate events, ranks India along with Philippines and Cambodia as the most affected countries in 2013 accounting for 0.22 percent losses per unit of GDP. The World Bank[1] also reported that by 2080, the world agricultural productivity would decline by 3-16 % and IPCC (2007) foresees a

[1] http://www.worldbank.org/content/dam/Worldbank/document/CSA_Brochure_web_WB.pdf accessed on 21 February 2016

loss of 10-40% in food grain production with an increase in temperature during the period 2080-2100. In addition, the long-term impact of the El Nino-southern oscillations on Indian food grain production shows that there is an inverse relationship between sea-surface temperatures and production (Selvaraju, 2003). The CMIP5[2] model projections of the Indian summer monsoon variability due to climate change by Sharmila *et al* (2015) points to a moderate increase in mean rainfall in the future due to amplified thermodynamic conditions as a result of atmospheric warming. The authors also suggest that at the inter-annual timescale, both strong and weak monsoons are likely to increase in severity and frequency. As such, any significant variation in the monsoon pattern beyond those that are cyclical in nature would cause drastic changes in Indian agriculture.

Given a plethora of evidence revealing the significant alterations that impact agricultural systems, many policies and programmes have been developed and implemented in India. How successfully these programmes are depends largely on the institutional arrangements across different scales (Dubash and Joseph, 2016). NAPCC has provided some light in this direction by forming linkages between climate change and concerned sectoral ministries that have yielded a host of institutional innovations. In this paper, methodologically, we draw from reports of various government documents highlighting the facets of the programmes related to addressing agricultural systems in the face of climate change. We have also supplemented our understanding with available data on the progress achieved under specific programmes. The paper is organised in the following way: in the ensuing section, a brief outlook of the climatic situation in India is highlighted followed by the probable impending consequences of alteration in climate and underscores the effects of climate change on the agricultural economy. The next section elucidates pathways for adaptation and mitigation within the sector highlighting the various policy measures, programmes and investments in the sector. The concluding section, taking a leaf from Climate Smart Agriculture source book (FAO, 2013) reiterates the need to look at the diverse institutional arena within India and the complex interactions from a comparative policy framework given the multiplicity of climate discourses and strategies that aid in shaping the future course of action.

OVERVIEW OF THE IMPACT OF CLIMATE RISK ON INDIAN AGRICULTURE

Indian agriculture is a climate sensitive sector, especially rainfed agriculture that covers nearly 58 percent of the cultivated and contributes 40 percent of the country's food production (Prasad et al, 2015). Historic records showed that winter precipitation in India has increased significantly since 1954, while, the rainfall during the monsoon period has decreased across most regions (Pal and Al-Tabba, 2011). In addition, natural capital depletion and increased use of external inputs into the farming system have aggravated the impact of climate change. There are several studies that reveal the specific impacts of changes in climatic parameters on different crops and the associated consequences of altered conditions (IPCC, 2007; Barnwal and Kotani, 2013; Grover and Upadhya, 2014; Rao *et al*, 2015; Khan *et al,* 2009).

Apart from production and yield associated impacts, other areas such as water scarcity as a consequence of changes in temporal and spatial distribution of rainfall results in increased competition among diverse activities within agriculture and other sectors in the economy. This competition can escalate given the finite amount of utilisable water, i.e. 1123 billion cubic meters (bcm). In addition, the irrigation efficiency from surface water sources is only between 35 -40 % and groundwater 65-75 % (Agriculture Annual Report 2012-13). Abrol (1999) asserts that issues related to water management such as over exploitation of groundwater, irrigation inefficiency and lack of water conservation are likely to impact the production of rice and wheat. Short-term impacts related to water storage associated with successive durations

[2] Coupled Model Inter-comparison Project Phase 5

of dry and wet years provide an indicator of ground water stress. This is also a concern as there is an increase in the number of irrigation wells and the low adaptive capacity of the farmers to shift from high to low water utilising crops (Pavelic *et al* 2012). Palanisami et al (2010) also found a decrease in the net area irrigated by tanks.

Further, the predicted changes in the dynamics of insect pests population and geographic distribution have serious consequences on both crop production and food security. The frequency of pest outbreaks is likely to increase during extended periods of drought and intermittent heavy rainfall and pest management strategies are likely to be less effective (Sharma & Prabhakar, 2014). Four field experiments showed that sowing time and wheat cultivars influenced the aphid infestation in wheat; and an alteration in sowing time would be an effective adaptation strategy given the positive influence of temperature on aphid population (Chander *et al,* 2014). In addition, some of the likely impacts on soil due to the changed scenarios of atmospheric composition are soil erosion, water logging and soil salinity. It is estimated that 120.40 mha of the 328.73 mha land area is affected by various forms of land degradation, ICAR (2010).

CLIMATE CHANGE ADAPTATION AND MITIGATION FOR INDIAN AGRICULTURE

Adaptation can occur at various levels from the farm to the policy level, such as changes in agricultural practices, substitution or diversification, moving out of crop farming, aquaculture, and/or livestock rearing. Agricultural operations require incorporation of technology to improve land and water management for resource conservation and use efficiency. This can be achieved through technological advances such as efficient irrigation systems and the location and design of water storage facilities. Productivity enhancement requires adopting new and innovative farming techniques and more efficient and sustainable utilisation of resources. Green agriculture, organic farming as well as advances in molecular mechanisms for plant abiotic stress tolerance are important strategies to this end. Improved mechanisms for collection and dissemination of weather, soil and agricultural data for timely execution of farming activities is also an essential component towards adapting to climate change. The availability and accuracy of short term weather forecasts in irrigation scheduling has the potential to save water whn routine schedules result in unnecessary irrigation. These forecasts can improve irrigation efficiency and with longer records of weather forecasts, the current irrigation practices can relatively be streamlined and consequently a valuable adaptation strategy (Mishra *et al,* 2013). Remote sensing can also be used to study and monitor the response of vegetation and changes in growing seasons of crops that negatively impacts grain filling and consequently yield. As such, solutions for shift of planting season to avoid spring stress and measure of greenness can maximise crop production in view of changing climate conditions.[3] At the local adaptation level, dissemination of knowledge and assistance to farmers in coping with current climate risks via weather services, agro-advisories, insurance, community banks for seed and fodder, incentives to farmers for resource conservation are key. At the policy level, aspects that need to be streamlined relate to rampant conversion of agricultural land to non-agricultural uses as well as fragmentation mainly as a result of uncertain land rights and tenures, land reform laws related to tenancy, wasteland utilization and access to common property.

Kumar et al (2012) using a crop-based approach for rainfed agriculture provided adaptation and mitigation strategies. Some of the examples include identifying suitable varieties tolerant to heat stress, salinity, submergence and augmented nutrient use efficiency among others. Specifically relating to site specific nutrient management, Kumar et al (2011) showed that neem cakes coated with Urea enhanced nitrogen use efficiency that has resulted in reduced GHG

[3] http://www.downtoearth.org.in/video/remote-sensing-the-biggest-tool-to-study-climate-change-56115 accessed on 9 December 2016

emissions and nitrate groundwater pollution. Dev (2016) suggested that, the year 2016 being the international year of pulses, the governments' three-pronged strategy that focuses on yield, insurance and price can boost its domestic output. As such,diversification towards pulses is seen as as one climate resilient agriculture strategy, that Swaminanthan also suggested through "pulse panchayats" (ibid).

Mitigation on the other hand is a challenging process and agriculture has a high technical mitigation potential which has been estimated at 5.5–6 Gt of CO2 per annum by 2030, if best management practices are widely adopted (Smith *et al*, 2007). Some of the mitigation options listed under the IPCC that developing countries such as India can adopt also has co-benefits of food security. Further, diverse management of agricultural systems and practices like agro-forestry helps in the removal of atmospheric CO2 in the form of soil organic matter (Lal, 2004). Also, the use of crop residue as a source of fuel also helps to reduce GHG emissions (Cannell 2003) and minimises the pressure on use of fossil fuel. India could also utilise carbon financing from adopting organic farming, bio-gas and system of rice intensification under international schemes such as Reducing Emissions from Deforestation and forest Degradation (REDD) and Clean Development Mechanism (CDM).

Within this narrative of evolving technical expertise and disseminating effective information for climate change adaptation and mitigation in the agriculture sector, the non-technical and public goods characteristics of soil and water conservation that condition farmers' technology choice also highlights the need to simultaneously promote strategies that address institutional constraints and internalise local externalities. This induces strategies for collective participatory action at the community and landscape level. Thus, synergising the biophysical aspects of agricultural operations with the community and institutional factors that determine local demand and viability of interventions. To this end, an attempt has been made to briefly describe the current policies and programmes that are implemented in the agricultural sector.

Programmes Related to Natural Resource Management Affecting Agriculture

The ICAR's NRM Division addresses components relating to land degradation, low water productivity, soil health deterioration and low nutrient use efficiency, abiotic stresses including climatic aberrations and loss of tree cover and deterioration in ecosystem services. There have been various watershed development programmes (WDPs) implemented by the Agriculture and Rural Development Ministries and up to the end of 11th FYP period, an area of approximately 58 million ha has been developed. The other programmes relating to natural resources conservation include ; Command Area Development and Water Management Programme, Repair, Renovation and Restoration of Water Bodies, Vidarbha Intensive Irrigation Development Programme, National Mission on Micro Irrigation, National Project for Management of Soil Health and Fertility, National Project on Organic Farming and National Afforestation Programme. Apart from those mentioned above, there are externally aided projects like the sodic land reclamation and development project with World Bank support, crop diversification in Himachal Pradesh with the assistance of Japan International Cooperation Agency. Complementing the NRM programmes and the high sensitivity of crop risks and uncertainty in agriculture, the government has piloted several initiatives such as the Integrated Scheme for Farmers Income Security, Pilot Weather based Crop Insurance Scheme, Pilot Coconut Palm Insurance Scheme and Livestock Insurance Scheme, to name a few. The Centre also created the National Adaptation Fund on Climate Change (NAFCC) with a provisional budget of Rs.3.5 billion for the years 2015-17 and 1.815 billion for the financial year 2017-18 with NABARD as the National Implementing Entity to address state. Table I shows the proposals currently sanctioned by the NAFCC.

Table 1: Projects Sanctioned Under NAFCC

Name of Project	Project Outlay (Rs. In Crores)
Towards Climate Resilient Livestock Production System in Punjab	17.40
Conserve water through the management of run-off in the river basin to reduce vulnerability and enhance resilience for traditional livelihood in Nuapada, Odisha	20.00
Sustainable Livelihoods of Agriculture-Dependent Rural Communities in Drought Prone District of Himachal Pradesh through Climate Smart Solutions	20.00
Model Carbon Positive Eco-Village in Phayeng of Manipur	10.00
Management and rehabilitation of coastal habitats and biodiversity for Climate Change Adaptation and Sustainable Livelihood in Gulf of Mannar, Tamil Nadu, India	24.74
Promotion of Integrated Farming System of Kaipad and Pokkali in coastal wetlands of Kerala	25.00
Sustainable Agriculture Development through Expansion, Enhancement and Modelling, Mizoram	10.38
Climate Adaptation Strategies in Wetlands along Mahanadi River Catchment areas in Chhattisgarh	21.47
Climate Resilient Sustainable Agriculture in Rain-Fed Farming (Kandi) Areas of Jammu and Kashmir	22.52
Spring-shed development works for rejuvenation of springs for climate resilient development in the water stressed areas of Meghalaya	22.92
Resilient Agricultural Households through Adaptation to Climate Change in Mahbubnagar District, Telangana	24.00
Integrated surface Water Management through Rejuvenation of 20 tanks and 32 village ponds for Climate Change Adaptation in Puducherry	16.76
Total	**235.19**

Source: *NABARD*

These government programmes/initiatives are seen as aligned to the climate smart agriculture initiatives taken in the recent past. It is observed that the convergence of programmes with the interventions is high and some of them cross-cutting. There are also a few programmes stated above that have multi-domain coverage of interventions (Parappurathu *et al,* 2014). However, the caveats observed by the author is that climate change mitigation has not been given equal priority as much as adaptation interventions, weather related early warning systems, pest and disease outbreak alerts, indigenous practices and protection of common property resources (CPRs). Enveloping all these areas is essential to strengthen social safety nets for communities in transition given emerging climatic events altering agriculture systems. The National Policy for Farmers, 2007 also broadly emphasised the protection and improvement of land, water, biodiversity and genetic resources for sustained agriculture and encompass all the agricultural programmes already taken by the government where not only crop production, but farmer's well-being is prioritised. In COP21 held at Paris, India drew out its intended nationally determined contribution (INDC) that targets reducing emissions intensity of its GDP by 33-35% by 2030, compared to 2005 levels. It specifically looks at contributing in vulnerable sectors such as agriculture, forestry and water resources among others by enhancing investments in development programmes. Some of these programmes have been elaborated in the following sections.

PROGRAMMES ON THE AMELIORATION OF CLIMATE RELATED RISKS AND NEGATIVE IMPACTS ON AGRICULTURE

National Mission for Sustainable Agriculture (NMSA)

The launching of the National Action Plan on Climate Change (NAPCC) in 2008 based on principles adopted

from the UNFCCC[4] have resulted in eight national missions that stress on co-benefits or development enhancing measures through interweaving climate objectives into existing policy-making decision-making and institutions. The National Mission for Sustainable Agriculture being one of the eight missions conceived to address agricultural risks associated with climate change with an allocation of Rs.130.54 billion. The specific interventions in the mission are related to rain fed area development, on-farm water management, soil health management and lastly, climate change and sustainable agriculture-monitoring, modelling and networking. Of them On-Farm water management has received the largest funds (Figure 1). The mission also highlights the need to infuse traditional knowledge for in-situ conservation of genetic resources where the Panchayat Raj Institutions are actively involved in the planning and implementation of the Mission Implementation Plan in every State. As of 2014-15, the state-wise allocation of funds for rainfed area development, on farm water and soil health management are Rs. 3.04 billion, Rs. 9.63 billion and Rs. 878.8 million. Within this mission, 6780 farmers have been trained in soil health management as of 2015-16 (indiastat.com).

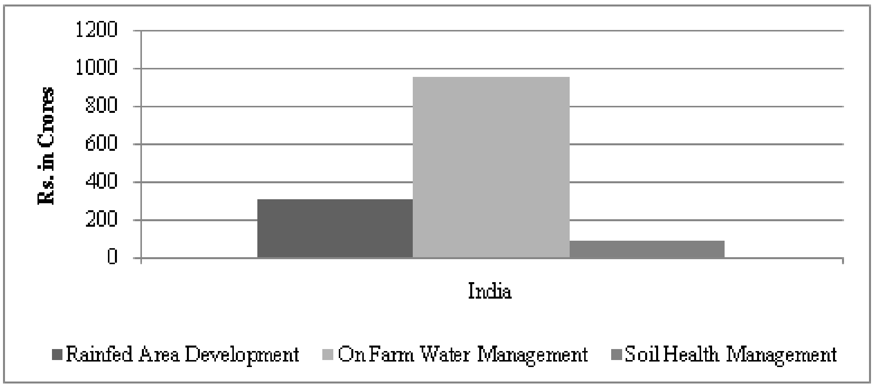

Figure 1: Funds Released Under Components of National Mission for Sustainable Agriculture (NMSA) in India

Source: *Indiastat.com*

Some of the recent deliverables, activities and targets are shown in Table II. While, the progress of the NMSA is accounted through the achievements of the DAC's other ongoing programmes through convergence as well as synochronisation with NICRA so there are not overlapping programmes[5].

Table 2: Summary of Deliverables, Activities and Achievements of NMSA

Mission Deliverables	Mission Activities	Target for 2013-17	Target for 2013-14	Achievement in 2013-14
Horticulture	Horticulture Area Expansion (Lakh Ha)	11	1.2	1.04 (86)
Seed	Seed Processing (Lakh Qtl)	10	2	3.64 (182)
Agriculture Supply Chain Management	Agri Market Creation of Storage (Lakh Mt.)	230	45	42.93 (95)
Livestock and Fisheries	Increase in Fish Production (Fingerling Production)	220350	37818	37132 (99)

Source: *Compiled from Indiastat.com*

Note: *Figures in the parentheses indicate percentages to total*

National Mission/Initiative on Climate Resilient Agriculture (NICRA)

The word resilience in agriculture indicates the time taken for the sector as a whole to achieve a state of

[4] United Nations Framework Convention on Climate Change

[5] *www.ifmrlead.org/wp-content/uploads/.../7_**NMSA**%20Brief_CDF_IFMRLEAD.pdf accessed on 12* November 2016.

equilibrium. India being agriculture based society for millennia, our traditional knowledge and adaptive capabilities has so far cushioned the sector across different landscapes and vagaries of weather. However, in modern agriculture, the complexities and vulnerabilities faced are much higher. In 2011, a network project - National Initiative on Climate resilient Agriculture (NICRA) was launched to enhance resilience of Indian agriculture to climate change through research, technology demonstration and capacity building. The Modules of the NICRA include interventions in natural resource conservation, crop production for high sustainable yield index, livestock and fisheries management and lastly institutional interventions. Several States in India have been allocated funds under this scheme totalling over Rs. 3 billion, with Delhi, Andhra Pradesh, Uttar Pradesh and Karnataka securing funds over Rs. 200 million over the last four years (Figure 2). "Technologies such as on-farm water harvesting in ponds, supplemental irrigation, introduction of early-maturing drought-tolerant varieties, paddy varieties tolerant to sub-mergence in flood-prone districts, improved drainage in water-logged areas, recharging techniques for tube wells, site specific nutrient management and management of sodic soils, mulching, use of zero till drills were enthusiastically implemented by the farmers in NICRA villages across the country (ICAR 2016)". A study by Prasad et al (2015) has described farmer participatory technology demonstrations carried out in 100 vulnerable districts with approximately 1259 natural resource management interventions. The results of these interventions have demonstrated significant increase in crop yield by 20-40% across cropping zones and have been well received by farmers.

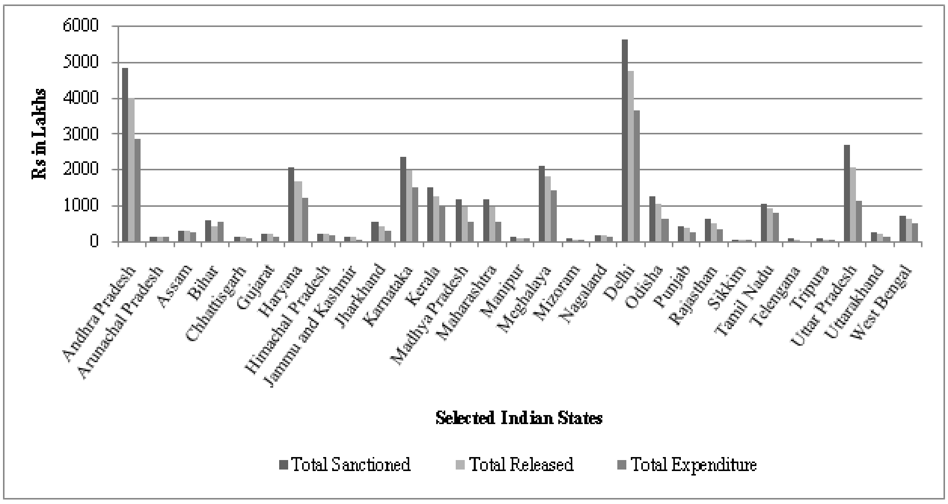

Figure 2: State-Wise Total Funds Allocation, Released and Utilised for Agriculture and Allied Sectors under NICRA Scheme in India in the Last Four Years

Source: *Compiled from Indiastat.com*

Climate Smart Agriculture (CSA)

Current discussions on agricultural development have been dominated by Climate Smart Agriculture as it seeks to unite the agendas of agriculture, development and climate change into one. The Climate Smart Agriculture Source book published by the FAO at the second global conference on Agriculture, Food security and Climate Change explicitly elaborates the concept with the intention of benefitting the small farmers in developing countries. The technological, policy and institutional interventions are related to seed, water, energy, nutrients and risk-averting insurance instruments to safeguard and bring stability to agriculture and farmers. The climate smart interventions are location specific and compatible with the skills and capital available with the farmers. The component most relevant is the ability of farmers, service providers (agencies) and relevant institutional capacity to respond effectively to long-term risks associated with

climate variability and climate change. CSA also provides an impetus for enabling sustainable intensification (SI) and is complementary in its approach towards sustainable agriculture. It postulates increasing food production on the existing area by concentrated efforts that have lower environmental impact, enhance animal welfare, human nutrition and support rural economies towards sustainability (Campbell *et al*, 2014, Dinesh *et al*, 2015). Another CSA enabling component is precision farming/agriculture that seeks to optimise returns on inputs. It is implicit within this management strategy that a high level of crop knowledge is essential for very efficient and site-specific nutrient and water application given that mechanized systems and synthetic nitrogen fertilisers emit considerable GHG emissions (Niggli *et al*, 2009). Innovative financing is another enabling component advanced under CSA that links climate and agriculture. Finance sourced from both the public and private sectors for implementation of CSA strategies along with integration and coordination of programmes and policies are essential. As institutional arrangements play a key role across diverse landscapes, the scaling up of climate-smart strategies would need appropriate institutional and governance mechanism that cater to context specific priorities of the agricultural landscape.

Farmers who own 0.38 to 1.40 hectares of land constitute 85 percent of total land holdings in India. These small farmers are most likely to be affected by climate change and need to move towards climate smart agricultural strategies to secure their livelihoods and stay sustainable. CSA in India is currently directed by knowledge and research inputs from National Agricultural Research Systems comprising of State Agricultural Universities and Indian Council of Agricultural Research, CGIAR Research Program on Climate Change, local authorities, and civil society. Researchers collaboratively have been testing and applying a series of agricultural interventions such as laser assisted precision land leveling, climate information services and *NutrientExpert* and *GreenSeeker.* The latter two are a computer based nutrient management tools for providing location specific recommendations on dose and time schedule for application of fertilisers required for maize and wheat. National agroforestry policy in India that seeks to incorporate trees and shrubs in farm lands to increase carbon sequestration and resilience to climate impacts is also recognized as a climate smart strategy.

Some specific cases of adoption of CSA strategies in the Indian context comprise of; efforts in establishing 'e-Arik' a village knowledge portal to provide agricultural information and communicate climate-smart agriculture practices in growing paddy. Similarly, the efforts to revive Khasi mandarin oranges and achieve food security among the *Adi* tribal community residing in the Siang river valley, North East India are seen as part of CSA (Saravanan & Change, 2011). Similarly, the International Maize and Wheat Improvement Centre (CIMMYT) is working with farmers in Karnal District, Haryana by demonstrating climate-smart technologies such as precision levelling to conserve water[6] as well as tools such as Leaf colour chart and GreenSeeker help to assess the fertiliser needs of crops. The government supported weather based crop insurance schemes that assisted close to 12 million farmers and solar energy for irrigation and community managed sustainable agriculure in Andhra Pradesh are other climate-smart technologies adopted in India (Tyagi *et al*, 2014). Taneja *et al* (2014) assessed the farmers preferences for climate smart agriculture in the Indo-Gangetic Plain (IGP) in the hope of synergising farmer's preferences with government programmes in the region. Farmers willingness to pay for various interventions was obtained using the scoring and bidding protocols via focus group meetings. Both the Eastern and Western Indo Gangetic farmers implicitly conveyed their WTP for a suite of new technologies ranging from laser land levelling, crop insurance to weather advisory services. However, the authors cautioned that large scale adoption of these interventions and technologies require access to adequate funds and capacity

[6] http://ccafs.cgiar.org/blog/how-can-we-%E2%80%98mainstream%E2%80%99-efforts-prepare-climate-risks-agriculture accessed on 31-12-2014

building. Future initiatives that are taking shape include, a project by the Tea Research Association in India along with the Southampton University on smartening tea plantation landscapes initially studying the North-East India that seeks to investigate climate variability, land-management practices and climate smart agriculture practices. Cocoa and coffee that thus far accounted for loss of primary and secondary forests could be fully converted to agroforestry plantations. With 10 million ha for each of these two crops they represent prime sources of currency for producing countries (FAO 2014) as well as the C storage potential could be ranked in the 10–100 t C/ha range for cocoa agro forestry and 10–150 t C/ha for coffee agro forestry.

It is postulated that operational success of CSA will require increasing institutional capacity building as small farmers are risk averse and have a limited capacity to accept risk with respect to adoption of climate smart agriculture interventions. There is a need for favourable policy intervention with monetary incentives to adopt such practices (Siedenburg *et al,* 2012).It is postulated that although upfront costs are higher in the short-term, the gains of higher incomes, resource savings, and improved ecosystem services, such as carbon sequestration would overtake the costs. In addition, the Research program on Climate Change, Agriculture and Food Security has piloted 27 climate smart villages of Haryana, where strategic participatory research, learning and dissemination of knowledge to local communities is recognised as an effective method to link science and development. Here as well, the aim can vary between the developed and the developing countries according to the level of agricultural development. The latter countries might focus on adapting their agricultural systems to meet the challenges faced due to changing climate conditions, whereas, the former may focus on reducing energy inputs and emissions, or encourage carbon trading. The challenge remains on orienting domestic institutions to help in design instruments for climate related adaptation strategies and financing them for successful implementation. However, the main challenge lies in making it inclusive of small and marginal farmers due to their poor natural resource base and access to credit and investment.

At a macro scale, to achieve climate-smart objectives within agricultural systems, a landscape approach is advocated via climate -smart landscapes. Therefore, at this juncture, climate change needs to be integrated into every national and regional development process built on smallholder- friendly institutional arrangements that is connected to farmers' preferences. The policy implications of such a dynamic approach would have extensive reach, affecting food security, livelihoods as well as soil and water conservation issues.

CONCLUSIONS

Research and action to date in the field of climate change has been largely in keeping with the Intergovernmental Panel on Climate Change definition, where in adaptation is merely a matter of 'adjustment'. However, the term has evolved to be understood as 'long-term and deep transformation'. Therefore, in the context of agriculture, to move forward given these agricultural, food security and livelihood enhancing programmes that exist in the domestic arena, few researchers propose a novel synergy of approaches in the wake of climate change. One such view for climate change adaptation is the operationalisation of the concept and measurement of adaptation for policy making via comparative politics literature. It is in this context, the relationship between the state, markets and society find relevance especially in relation to global environmental politics and environmental studies (Steinberg & Van Deveer, 2012). Insights from the subject can foster new institutional research that includes insights based on contextual location specific interests. Sieving through the various actors in the institutional setup is necessary to understand and then predict political behaviour which can produce policy recommendation, in this case conducive to governance of climate change and agriculture. In particular, informal

institutions play a dynamic role in India, though the State remains central and shapes local politics and policy despite the process of neoliberal globalisation currently taking place.

Within the climate change adaptation discussion, the effectiveness of formal and informal governance arrangements needs to be further analysed as community based adaptation from Ostrom's (2005) work shows potentials that can compliment formal institutional mandates. A pilot study reflects this point based on the application of participatory approach and the need to reconcile the mismatch between State policy recommendations and ground realities in Uttarakhand. It provides insights on vulnerability and adaptive capacity through mutual learning and exchange among communities within the watersheds of Uttarakhand State (Kelkar *et al*, 2008). Therefore, it is crucial that farmer’s perceptions are infused into decision making to develop appropriate adaptation policies (Udmale *et al*, 2014). Keeping this in mind, policies towards conservation of land need to be implemented in parallel with forest and water policies for the overall sustainable utilisation and management of resources.

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